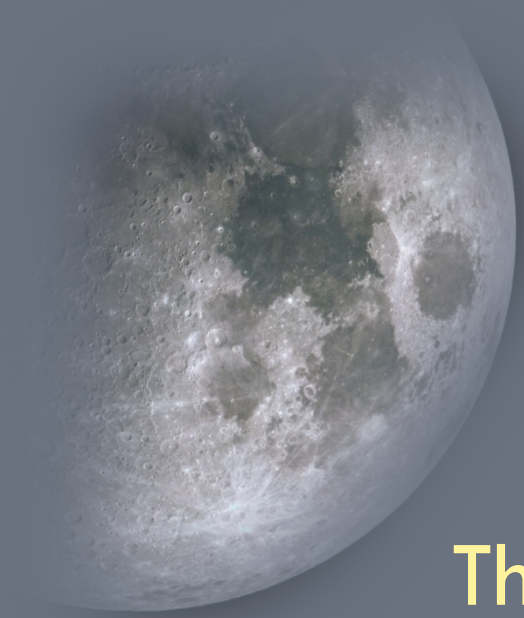
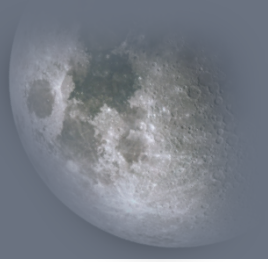


The Origin of Chromite Symplectites in Mg-suite Troctolite 76535: A New Look at an Old Rock

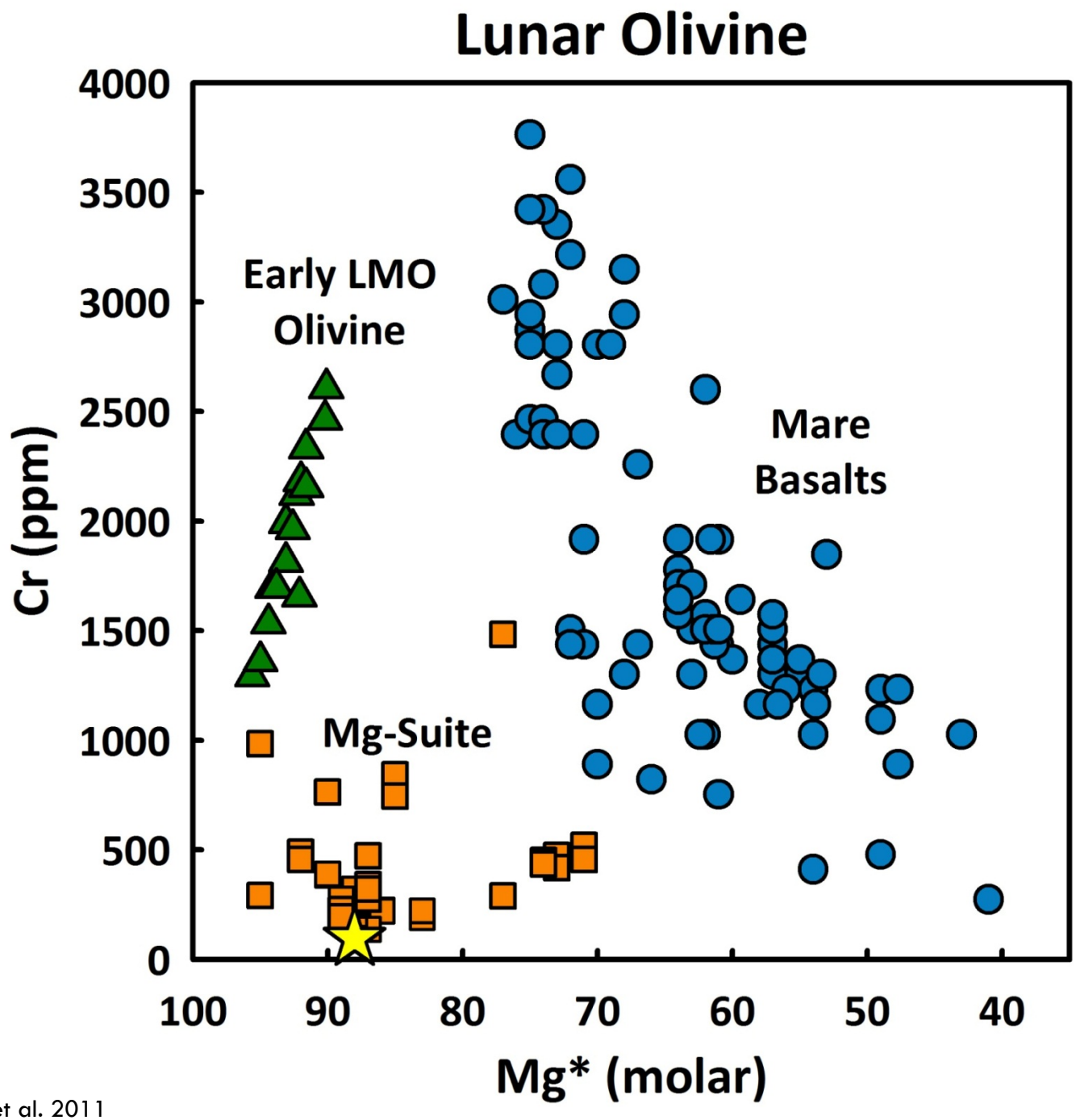
Steve Elardo
Francis McCubbin
Chip Shearer

Institute of Meteoritics, University of New Mexico

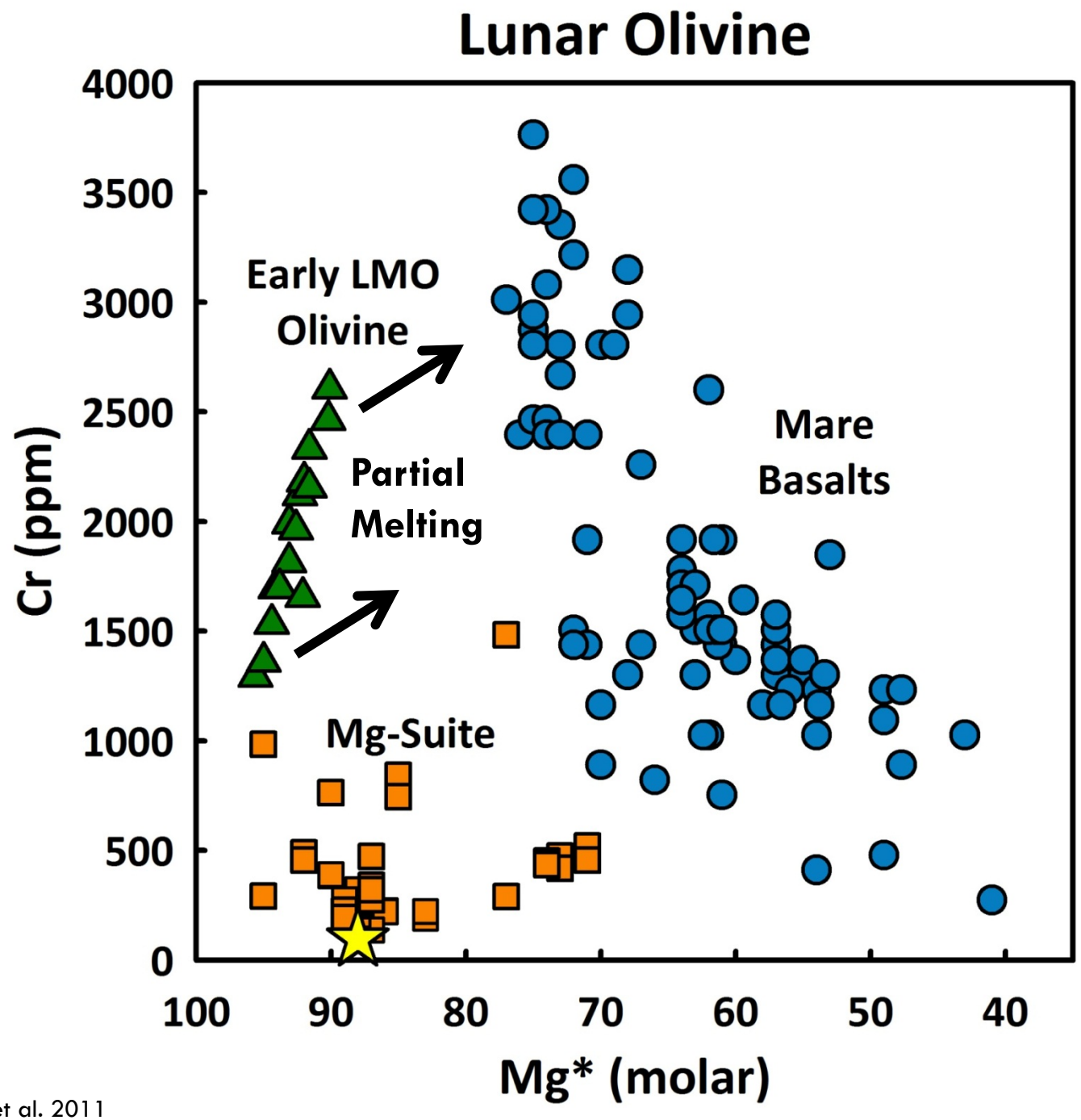
Troctolite 76535



- One of the largest, and the most pristine Mg-suite sample
  - 30% Olivine, 65% Plagioclase, 4-5% OPX, minor phases
- Pre-Serenitatis, ~4.23 Ga
- Olivine very low in Cr compared to mare basalt olivine
  - Lunar basalts usually higher in Cr than terrestrial basalts
  - Low lunar fO_2 makes Cr more incompatible during melting
- Symplectites consisting of chromite and CPX ± OPX

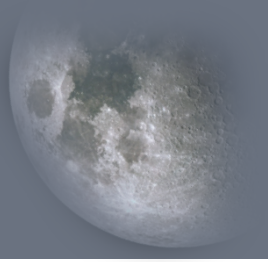


After Elardo et al. 2011



After Elardo et al. 2011

Troctolite 76535



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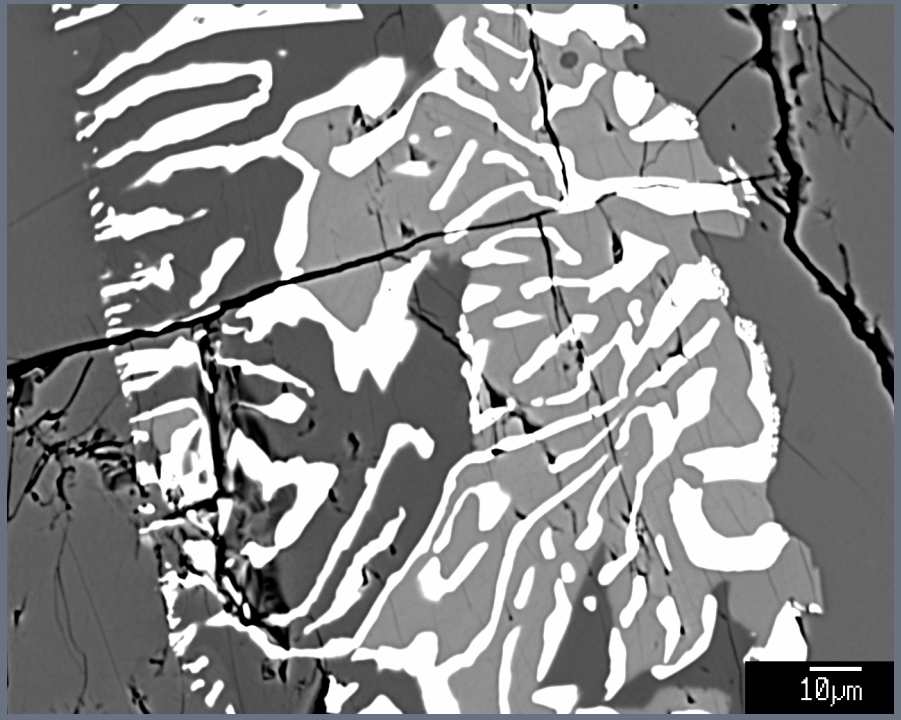
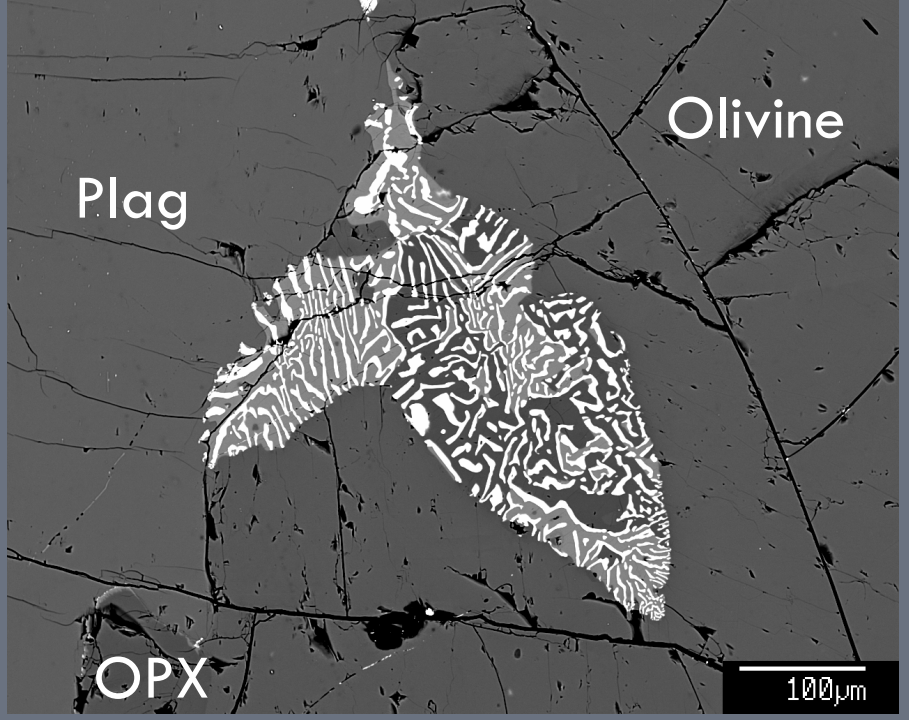
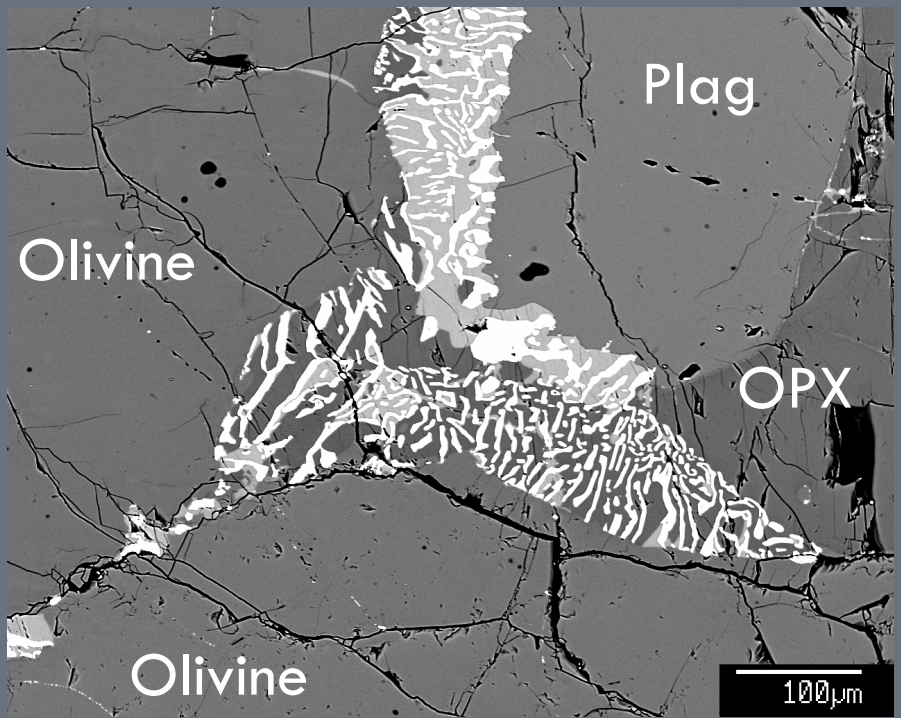
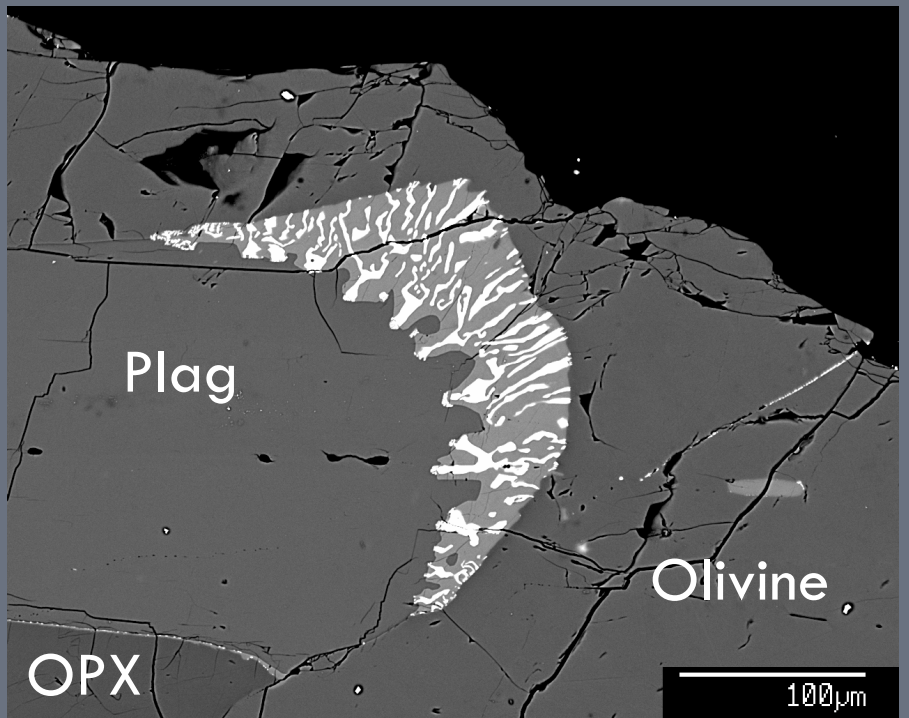

10µm


Olivine
Plag
OPX
100µm


Plag
Olivine
OPX
Olivine
100µm


Plag
Olivine
OPX
100µm

Questions

- Why is Cr highly concentrated in symplectites in 76535 when its olivine is Cr-poor?
- Is there a secondary process that explain the low Cr content of Mg-suite olivine? Or is it a reflection of low-Cr parental magma?
- What do the answers to these questions imply about the petrogenesis of the Mg-suite?
- This work aims to reassess symplectite formation

Symplectite Formation

1) Crystallization of trapped melt
   - Cr source: Chromite from trapped melt

2) Reaction between olivine and plagioclase

   2 Forsterite + Plagioclase = Enstatite + Diopside + Spinel

   - Cr source 1: Diffusion of Cr from olivine
   - Cr source 2: Remobilization of cumulus chromite

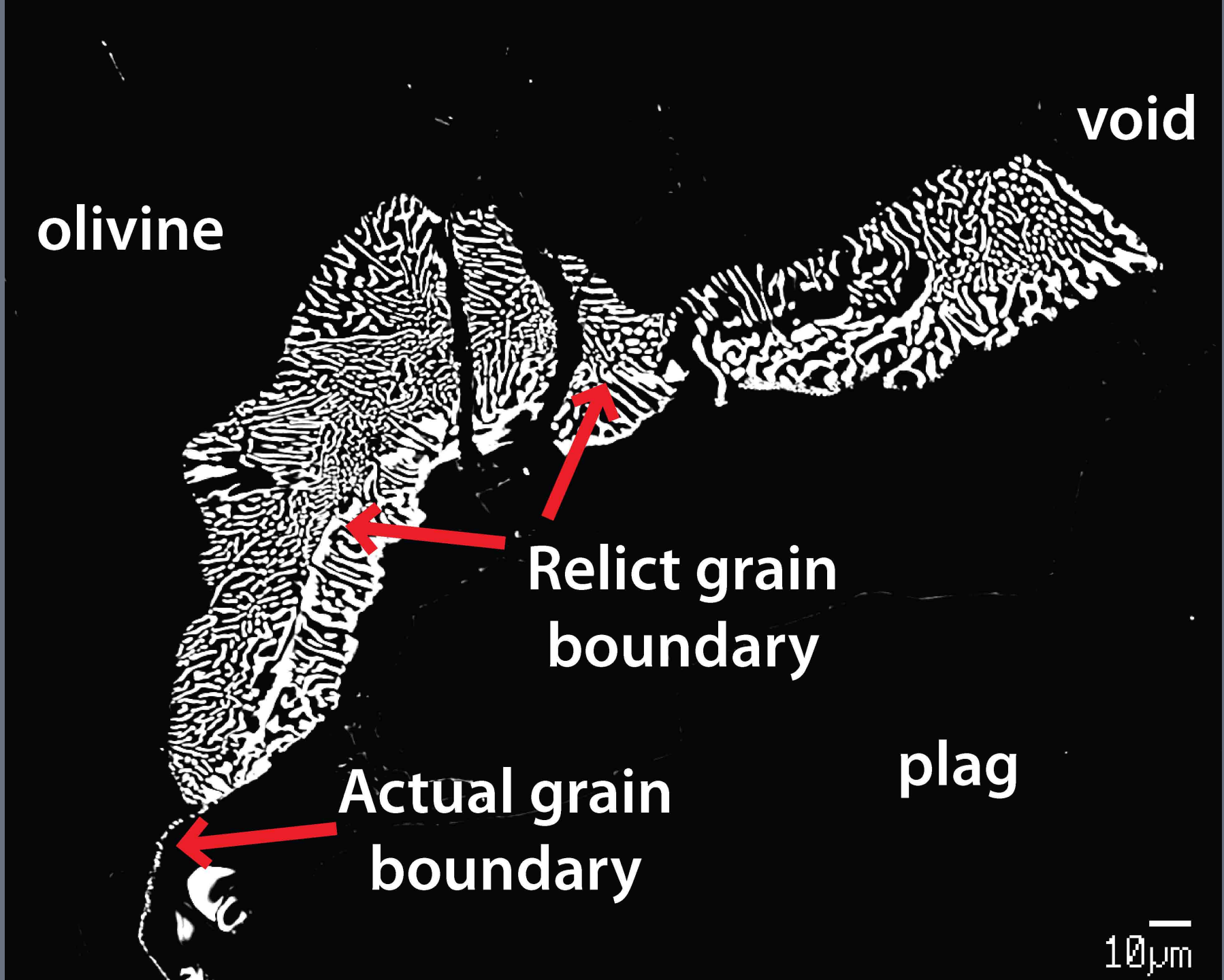
Refs: Gooley et al. 1974, Dymek et al. 1975, Bell et al. 1975, Albee et al. 1975

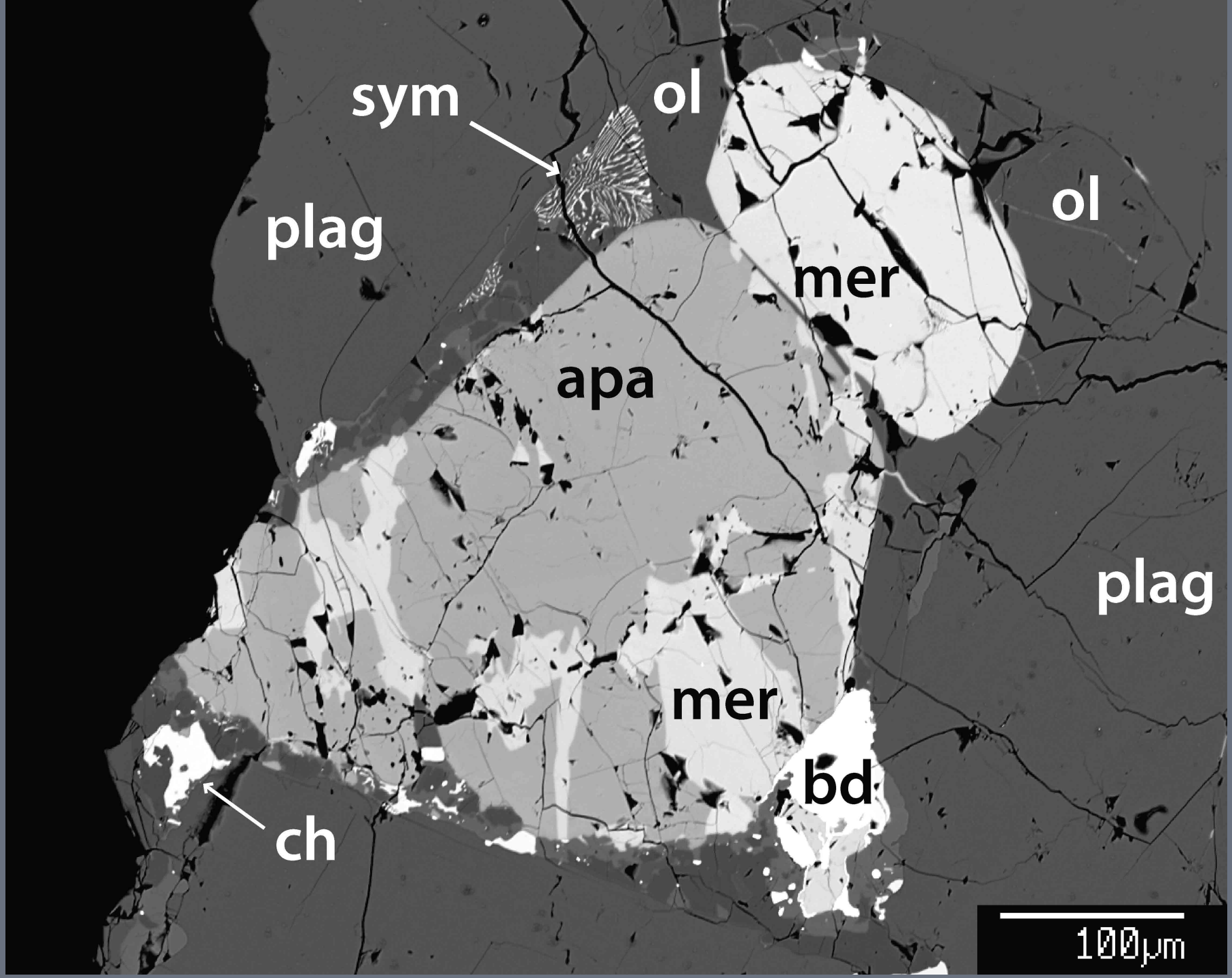
Important Observations

- Symplectites and chromite veins occur at or very close to olivine-plag boundaries
  - But most boundaries are symplectite free
  - Symplectites usually in close association with large OPX grains
- No cumulus chromite inclusions in olivine or clearly cumulus chromite grains
- Olivine-hosted melt inclusions chromite-free, pyroxenes low in Cr
- Trapped melt pockets contain only small amounts of chromite
  - Typically in symplectic texture

Trapped Melt Pockets?

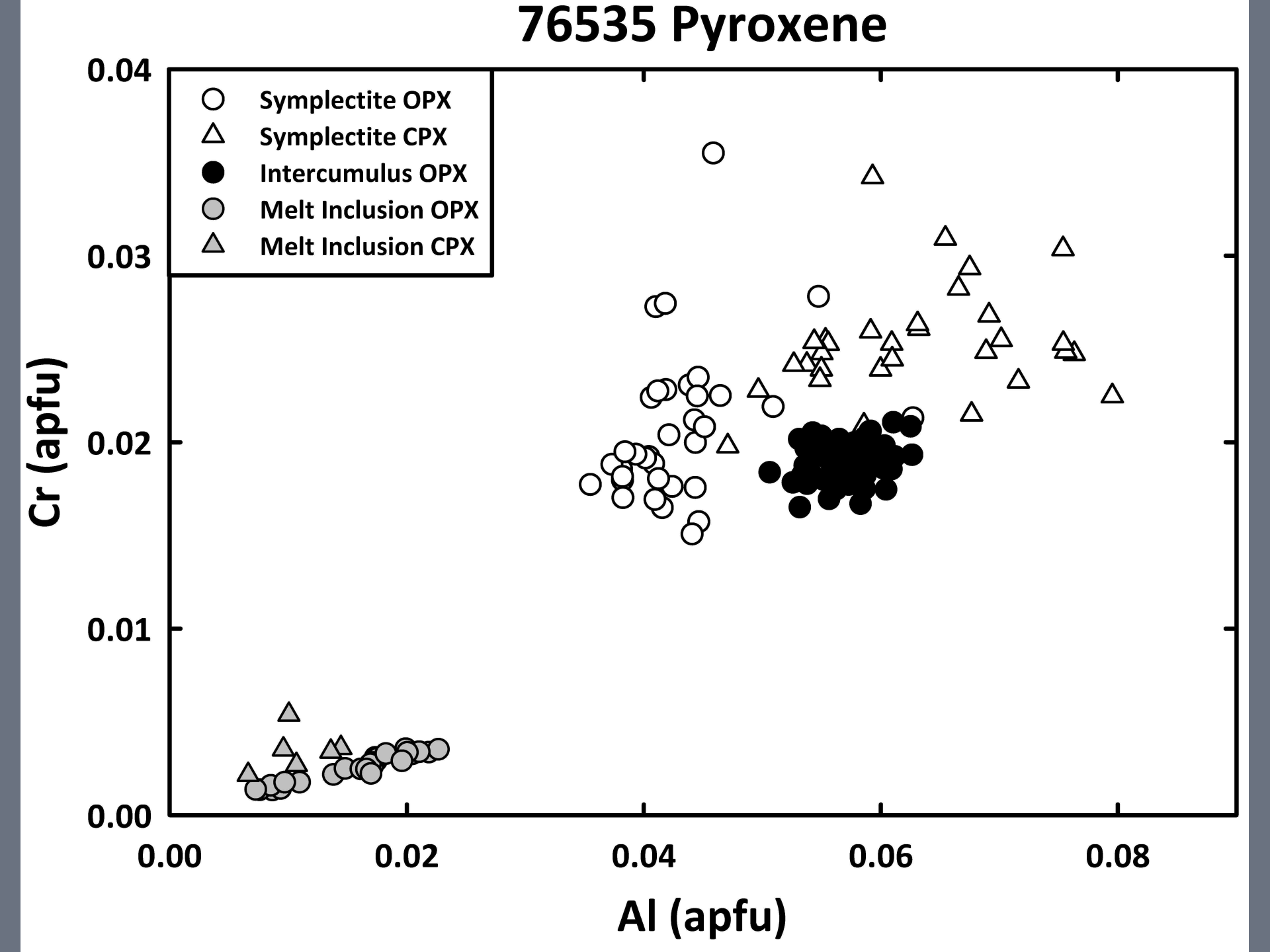
- Occurs in terrestrial layered intrusions
  - e.g. Skaergaard, with Fe-Ti oxides
- Requires significant adcumulus growth of olivine and plagioclase
- Symplectites do not contain other minor phases
- Not supported by textures

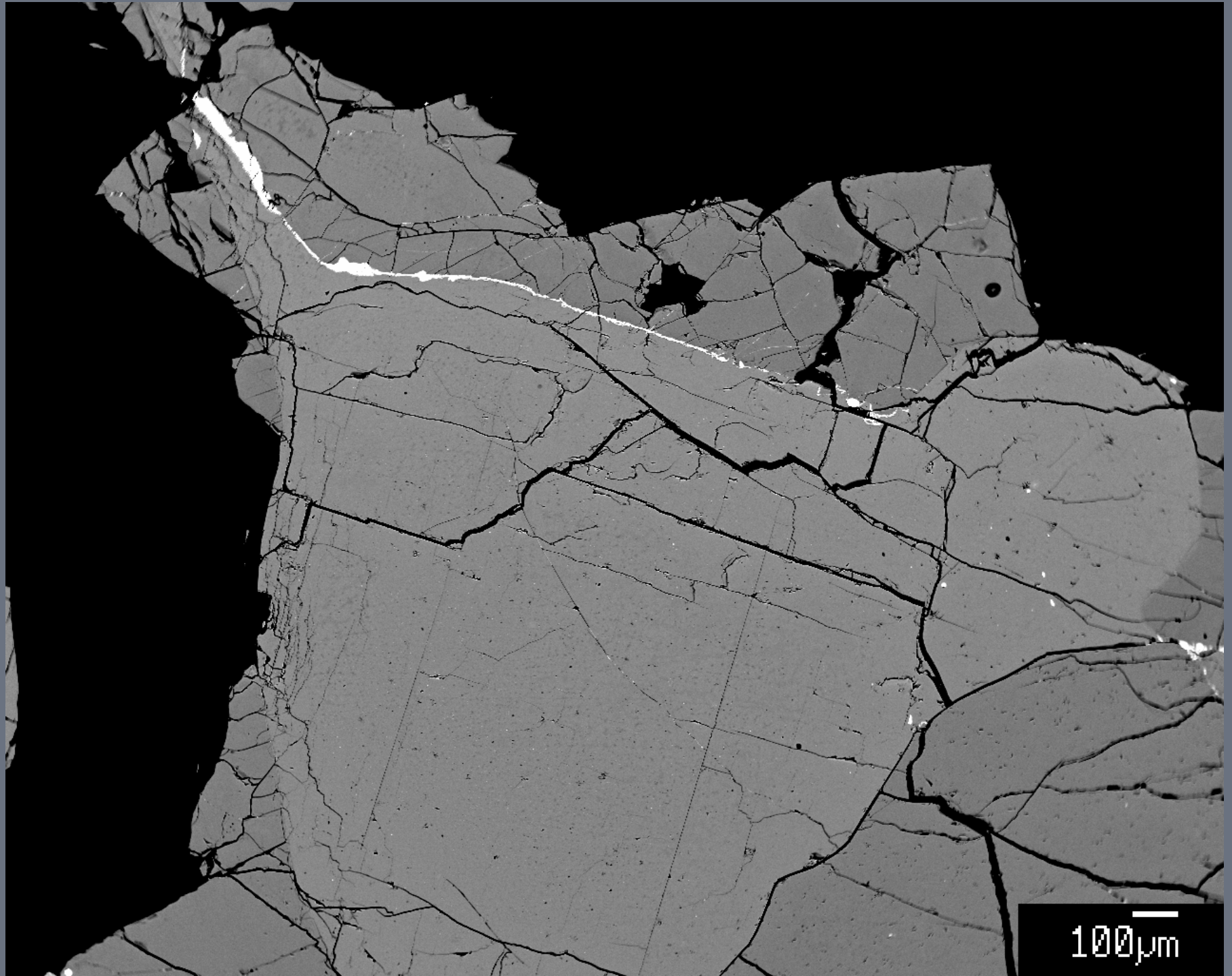

void
olivine
Relict grain boundary
plag
Actual grain boundary
10μm


sym
ol
plag
ol
mer
apa
plag
mer
bd
ch
100µm

Diffusion of Cr from Olivine?

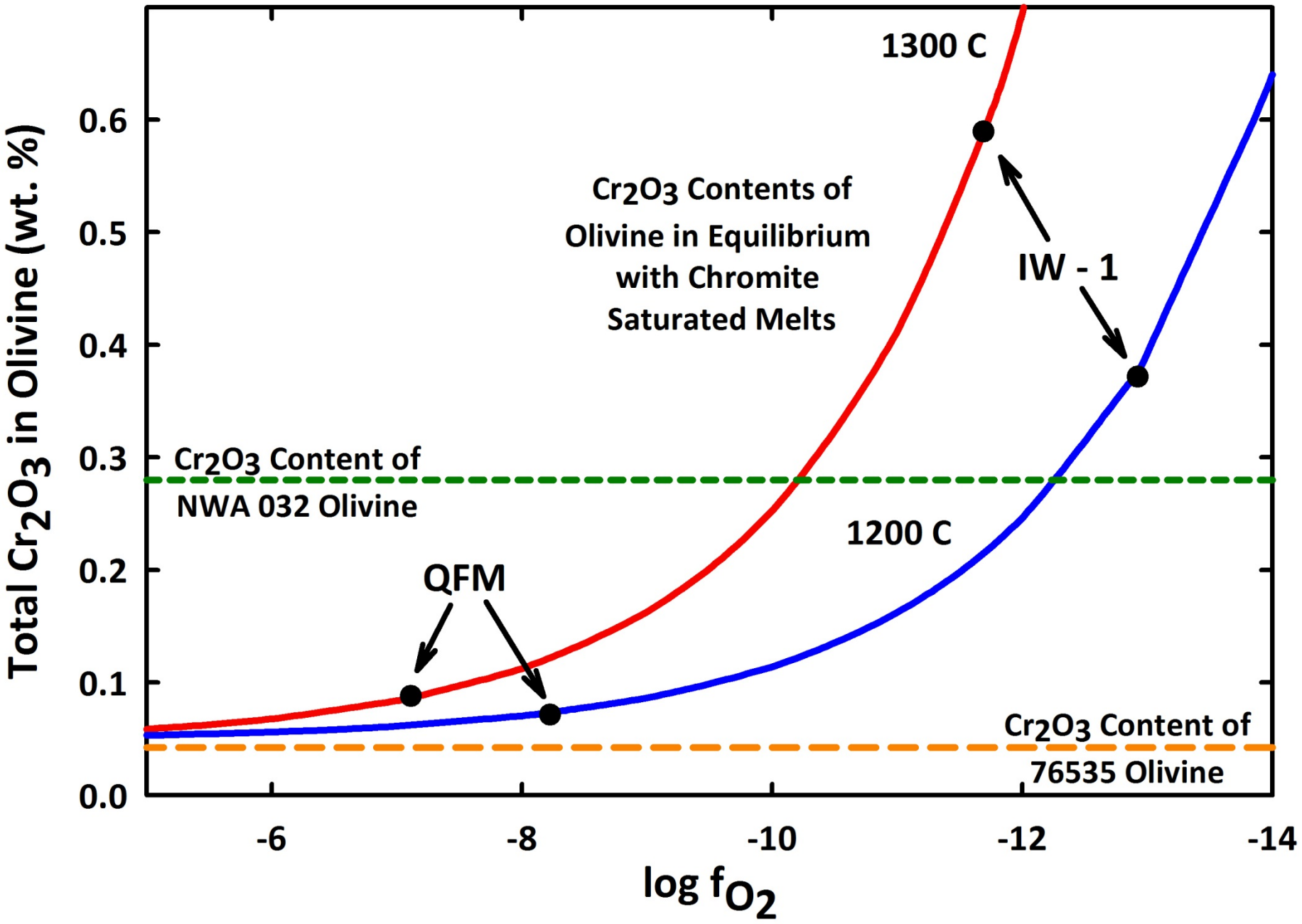
- Requires originally Cr-rich olivine
- Also requires Cr oxidation reaction
  - $2\ Cr^{2+}_{(ol)} + Fe^{2+}_{(ol)} \rightarrow 2\ Cr^{3+}_{(ch)} + Fe^{\circ}$
  - Fe-metal not observed in symplectites
- Inconsistent with uniformly Cr-depleted olivine, low-Cr content of melt inclusions, spare occurrence of symplectites


76535 Pyroxene
Symplectite OPX
Symplectite CPX
Intercumulus OPX
Melt Inclusion OPX
Melt Inclusion CPX
Cr (apfu)
Al (apfu)
0.00
0.01
0.02
0.03
0.04
0.00
0.02
0.04
0.06
0.08

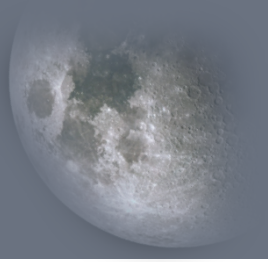

100µm

Pre-existing Cumulus Chromite?

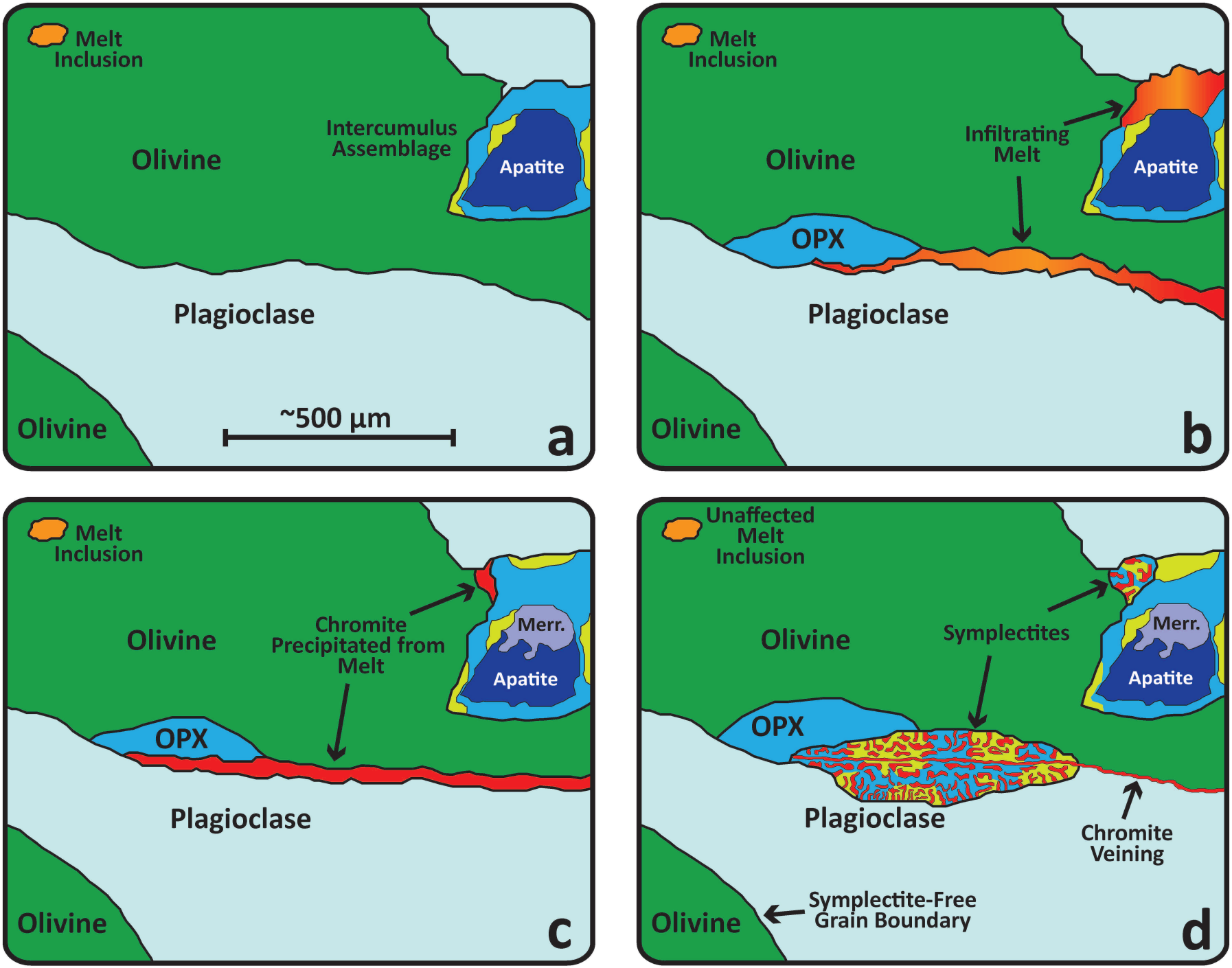
- Requires parental magma be chromite saturated
- Melt inclusion pyroxenes inconsistent with chromite saturation, no chromite in melt inclusions
- Olivine Cr content inconsistent with formation from a chromite-saturated melt


1300 C
Cr2O3 Contents of
Olivine in Equilibrium
with Chromite
Saturated Melts
IW - 1
Cr2O3 Content of
NWA 032 Olivine
1200 C
QFM
Cr2O3 Content of
76535 Olivine
Total Cr2O3 in Olivine (wt. %)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
-6
-8
-10
-12
-14
log fO2

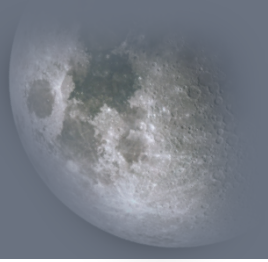
Cr in the Symplectites



- Internal sources of Cr inconsistent with multiple textural and geochemical observations
- Open system addition of Cr is required to explain symplectites in 76535
- Various factors rule out models involving differential settling of chromite, exogenous fluid
- Model of infiltration metasomatism of a chromite-saturated exogenous melt has fewest caveats


Melt Inclusion
Olivine
Intercumulus Assemblage
Apatite
Plagioclase
Olivine
~500 µm
a
Melt Inclusion
Olivine
Infiltrating Melt
Apatite
OPX
Plagioclase
Olivine
b
Melt Inclusion
Olivine
Chromite Precipitated from Melt
Merr.
Apatite
OPX
Plagioclase
Olivine
c
Unaffected Melt Inclusion
Olivine
Symplectites
Merr.
Apatite
OPX
Plagioclase
Chromite Veining
Symplectite-Free Grain Boundary
Olivine
d

Conclusions



- Crystallization of trapped melt, diffusion of Cr from olivine, and remobilization of cumulus chromite insufficient to explain symplectites in 76535
- Open system addition of Cr is required
- Infiltration of an exogenous melt is model most consistent with observations
- If intimate interaction with migrating melts was widespread in early lunar crust, it may help explain overlapping FAN and Mg-Suite ages